the ENERGY lab

PROJECT FACTS

Carbon Storage – ARRA-GSRA

Analysis of Potential Leakage Pathways and Mineralization in Caprocks for Geologic Storage of CO_2

Background

The overall goal of the Department of Energy's (DOE) Carbon Storage Program is to develop and advance technologies that will significantly improve the effectiveness of geologic carbon storage, reduce the cost of implementation, and prepare for widespread commercial deployment between 2020 and 2030. Research conducted to develop these technologies will ensure safe and permanent storage of carbon dioxide (CO_2) to reduce greenhouse gas (GHG) emissions without adversely affecting energy use or hindering economic growth.

Geologic carbon storage involves the injection of CO_2 into underground formations that have the ability to securely contain the CO_2 permanently. Technologies being developed for geologic carbon storage are focused on five storage types: oil and gas reservoirs, saline formations, unmineable coal seams, basalts, and organic-rich shales. Technologies being developed will work towards meeting carbon storage programmatic goals of (1) estimating CO_2 storage capacity +/- 30 percent in geologic formations; (2) ensuring 99 percent storage permanence; (3) improving efficiency of storage operations; and (4) developing Best Practices Manuals. Developing and deploying these technologies on a large scale will require a significantly expanded workforce trained in various carbon capture, utilization, and storage (CCS) technical and non-technical disciplines that are currently under-represented in the United States. Education and training activities are needed to develop a future generation of geologists, scientists, and engineers who possess the skills required for implementing and deploying CCS technologies.

The National Energy Technology Laboratory (NETL), through funding provided by the American Recovery and Reinvestment Act (ARRA) of 2009, manages 43 projects that received more than $12.7 million in funding that focus on conducting geologic storage training and support fundamental research projects for graduate and undergraduate students throughout the United States. The training and projects can be categorized under one or more of the DOE Carbon Storage Program's five Technology Areas: (1) Geologic Storage and Simulation and Risk Assessment (GSRA), (2) Monitoring, Verification, Accounting (MVA) and Assessment, (3) CO_2 Use and Re-Use, (4) Regional Carbon Sequestration Partnerships (RCSP), and (5) Focus Area for Sequestration Science. This training effort is conducting research and training related to confining layer (caprock) integrity.

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PARTNERS

None

PROJECT DURATION

Start Date	**End Date**
12/01/2009	11/30/2012

COST

Total Project Value
$299,930

DOE/Non-DOE Share
$299,930 / $0

PROJECT NUMBER

FE0001786

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U.S. DEPARTMENT OF ENERGY

Project Description

DOE partnered with Utah State University (USU) to conduct research and training to examine the nature and extent of confining layer integrity on CO_2 geologic storage. The effort analyzed the integrity of confining layers in exhumed (unearthed) analogs of CO_2 flow systems in order to determine the extent of CO_2 flow in possible leakage scenarios resulting from the presence of fractures or faults (Figures 1 & 2). Suitable geologic storage formations typically possess the ability to retain injected CO_2 due to low-permeability confining layers throughout more shallow formations that prevent upward CO_2 movement. Under normal circumstances, one molecule of CO_2 would require an extremely long time period (hundreds of thousands to a million years depending on confining layer thickness) to travel through one confining layer by diffusion alone. However, faulting or fracturing of the confining layer could allow accelerated CO_2 transport to shallower formations, including those considered to be drinking water sources.

The study helped constrain risk-based assessments and provided further insight into the design of carbon storage projects. USU examined a series of fractured and faulted shales and mudrocks, some of which were taken from pilot CO_2 storage sites in the Colorado Plateau region of Utah. All field work was conducted at four separate field sites at which USU has worked in the past.

Goals/Objectives

The goal of the project was to educate and train students in the science and technology of carbon capture and storage, with a focus on geologic storage. The project investigated the integrity of caprock in exhumed analogs of CO_2 flow systems in order to determine the processes by which CO_2 may flow and bypass sealing rock. USU is focusing on the presence of fractures or faults in caprock, as they are one of the key features that may lead to seal failure. Primary project objectives included: Primary project objectives included:

- Determining the nature of the caprock formation and early-stage growth of fractures in low-permeability shales and mudstones.
- Determining and characterizing key conditions that affect CO_2 flow through fractures/faults in caprock formations at time scales relevant for CO_2 injection and migration.
- Assessing the mechanisms that diminish or improve sealing quality of fractures/faults in seals.
- Building simple geometric and geostatistical models to determine the distribution of fractures, faults, and their relation-ships to CO_2 flow and /or mineralization within the rocks.

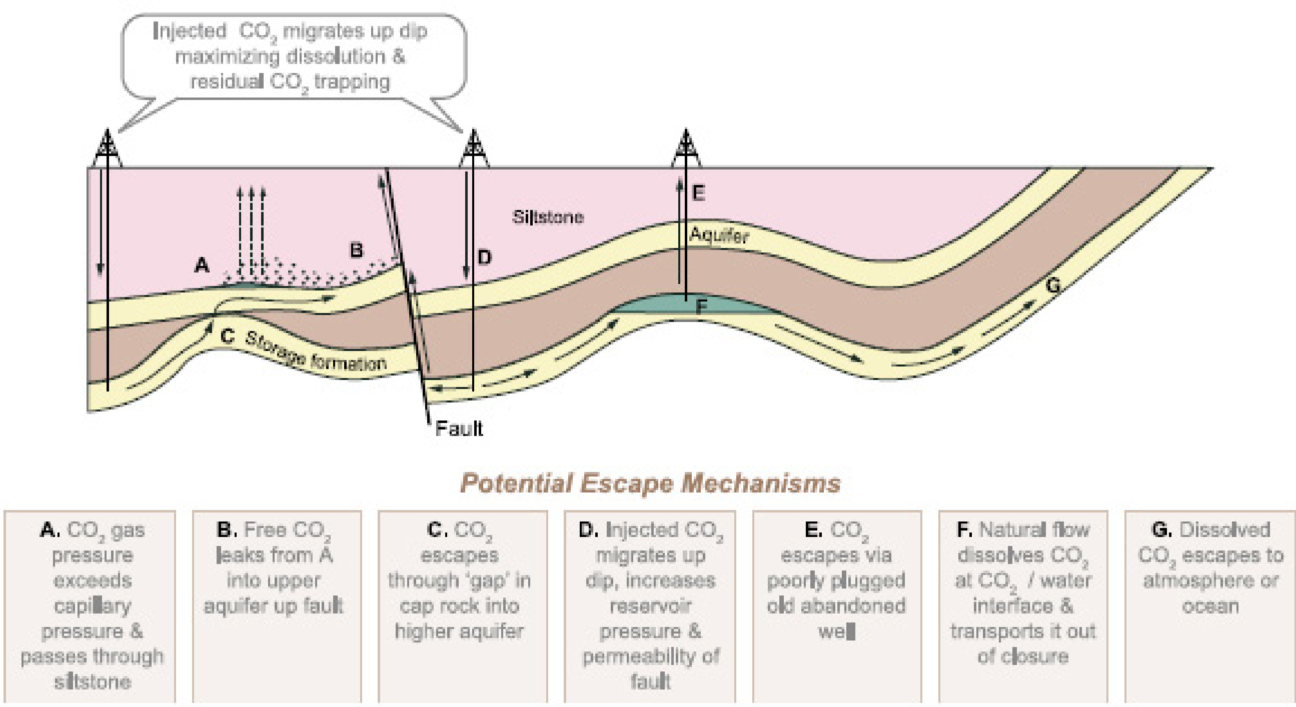


Figure 1. Potential leakage pathways must not neglect the effect of fracture networks in caprock.

Accomplishments

- At the conclusion of this project, twelve personnel had accumulated 6,319 training-related hours under the program.
- Developed a high-pressure laboratory apparatus to perform analyses of CO_2-water-rock interaction with CO_2 at reservoir pressure to run tests on confining layer samples.
- Examined the mechanical stratigraphy of a natural analog for geologic CO_2 storage confining layers and determined the geologic factors that influence its variability.
- Developed methods to correlate wireline log derived properties with field based observations as part of the effort to characterize confining zone integrity.
- Characterized seal bypass in four naturally formed reservoir seal systems (Figure 3) at centimeter (cm) to kilometer (km) scales. Findings indicate that cm to km scale fractures and faults create flow paths into and across confining layers.
- Developed a workflow to quantify mechanical and flow properties of rock, fractured rock, and fault zones
- Performed mechanical modeling of stresses and fracture development in these systems and determined that, using fluid pressures, they can be used to predict the fracture distribution in confining layers.
- A final report has been completed and is now available.

Benefits

The overall results of the project made a contribution to the scientific, technical, and institutional knowledge necessary to establish frameworks for the development of commercial-scale CCS, as well as constrain risk-based assessments and design of carbon storage systems. The project provided an added benefit of improving scientific understanding of the impacts of natural or induced small and large-scale fractures or faults in mudstone, shale, and siltstone seals on CO_2 flow, a contribution to the programmatic goal of insuring 99 percent storage permanence. Further, the project provided opportunities for students to learn methods used to conduct geologic analyses for determining the suitability of future carbon storage sites, gain experience with methods used to develop and run models to assess the fate of CO_2 in the subsurface, and investigate the key aspects of assessing the processes and risks of a confining layer breach and mitigation in a carbon storage site.

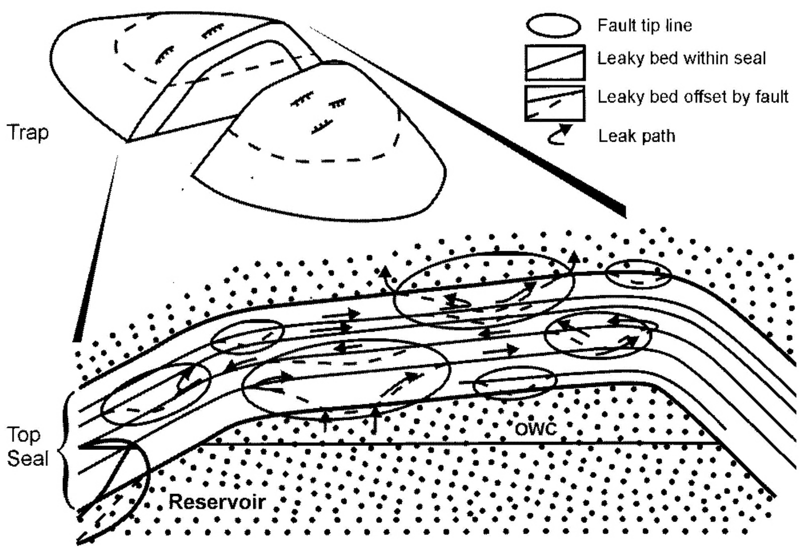
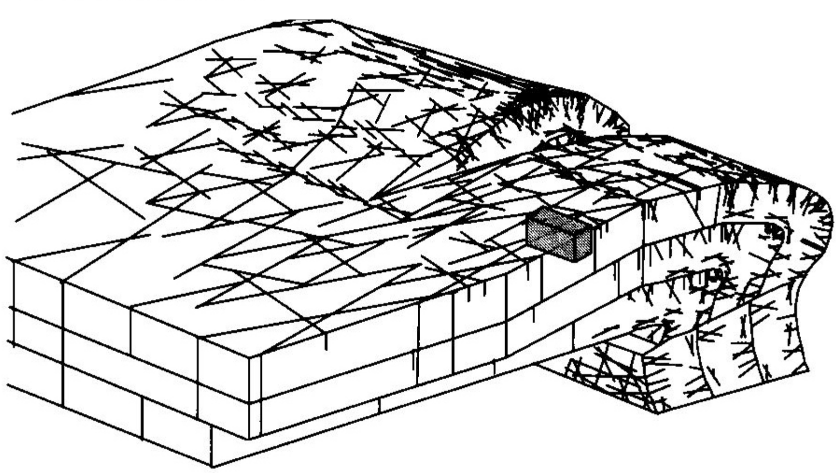


Figure 2: Schematic view of seal bypass systems envisioned for petroleum systems. Left frame shows fracture-linked leak path and complex fracture networks. The frame below shows fractures induced during different segment folding.



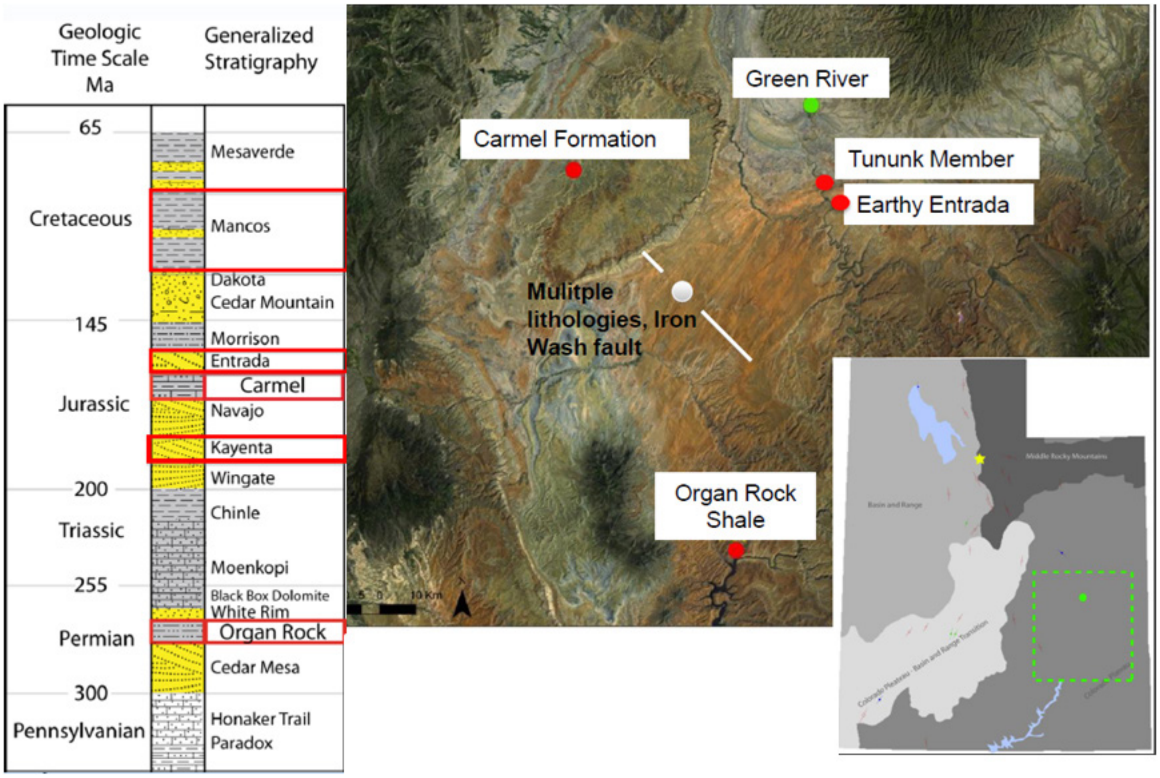


Figure 3: Four seal lithologies used in seal bypass characterization.